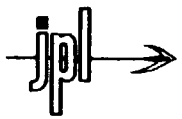
TECHNOLOGY READINESS STUDY

PRESENTATION TO

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY STUDY, ANALYSIS AND PLANNING OFFICE (RX)

July 28, 1976

JET PROPULSION LABORATORY
California Institute of Technology
Pasadena, California

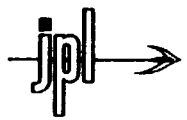


TECHNOLOGY READINESS STUDY
OBJECTIVES

- TO DEVELOP INFORMATION FOR THE STUDY, ANALYSIS, AND PLANNING OFFICE (CODE RX) TO SUPPORT ITS ROLE IN THE REVIEW AND ASSESSMENT OF TECHNOLOGY READINESS

- TO ASSESS THE READINESS OF A LIMITED SET OF TECHNOLOGY CANDIDATES FOR A SPECIFIC MISSION

- TO RECOMMEND CHANGE STRATEGIES FOR PROMISING TECHNOLOGY CANDIDATES



TECHNOLOGY READINESS STUDY
STUDY HISTORY

- PARENT STUDY
  - March, 1975 TO January, 1976
  - PRESENTATION TO OSS AND OAST December, 1976
- REVISED STUDY
  - February TO June, 1976
- SPONSOR INTEREST IN STUDY EVOLVED FROM CONTENT TO METHODOLOGY
- PRESENTATION WILL COVER RESULTS OF STUDY AND METHODOLOGY EMPLOYED

TECHNOLOGY READINESS STUDY
GUIDELINES

- SINGLE MISSION: MJ085
- LAUNCH VEHICLE: SHUTTLE/TUG (PARENT STUDY)
  SHUTTLE/IUS (REVISED STUDY)
- MISSION BASELINE: JPL MJO STUDY (OSS FUNDED)
- SCIENCE: MJOSWG PAYLOAD
- TECHNOLOGY BASE: MJS77 PLUS MJU79 (PARENT STUDY)
  MJS77 (REVISED STUDY)
- TECHNOLOGY READINESS DATE: July, 1980

TECHNOLOGY READINESS STUDY
SCOPE

- TECHNOLOGY CANDIDATES LIMITED TO ENGINEERING SUBSYSTEMS

- TECHNOLOGY CANDIDATES LIMITED TO JPL INTERNAL DEVELOPMENTS

  - SOLAR ELECTRIC PROPULSION AN EXCEPTION
    - READINESS ASSESSMENT APPLIED ONLY TO LOW THRUST NAVIGATION SOFTWARE, A JPL INTERNAL DEVELOPMENT
    - BENEFITS ASSESSMENT APPLIED TO COMPLETE PROPULSION SUBSYSTEM

- COST/BENEFIT INFORMATION ONLY QUALITATIVELY DEVELOPED

TECHNOLOGY READINESS STUDY

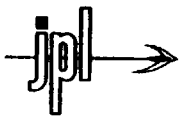
TECHNOLOGY ASSESSMENT - PURPOSE

- TO ASSESS READINESS OF CURRENT TECHNOLOGY CANDIDATES TO SUPPORT SPECIFIC PROJECTS OR PROGRAMS

- TO ASSESS THE RISK AND BENEFIT TO SPECIFIC PROJECTS OR PROGRAMS OF INCORPORATING TECHNOLOGY CANDIDATES

- TO ASSESS THE CAPABILITY OF EXISTING DEVELOPMENT PROGRAMS TO SUPPORT A SPECIFIC PROJECT OR PROGRAM

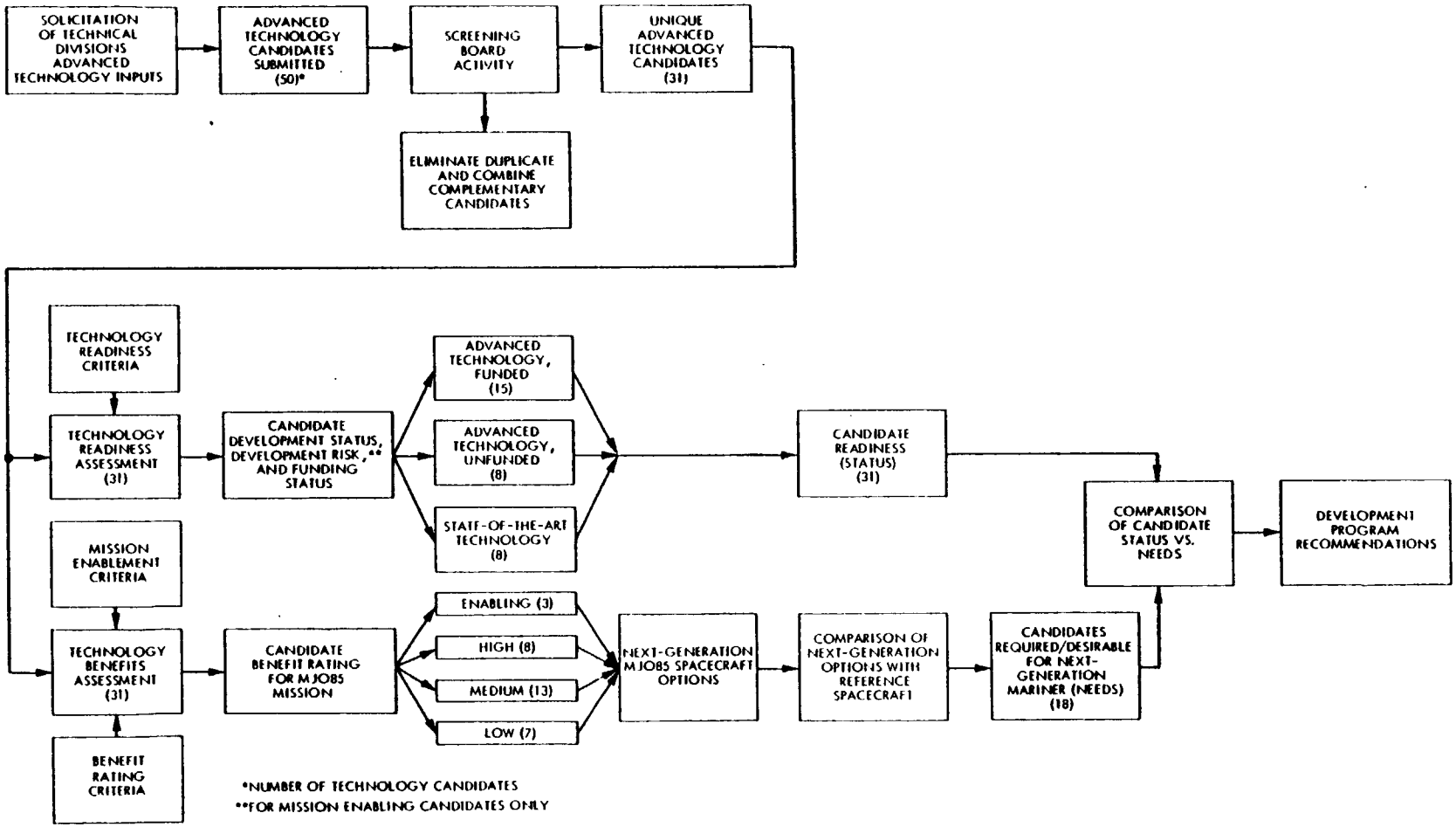
- TO RECOMMEND MODIFICATIONS TO EXISTING DEVELOPMENT PROGRAMS REQUIRED TO SUPPORT A SPECIFIC PROJECT OR PROGRAM



TECHNOLOGY READINESS STUDY
KEY CONCEPTS

- MISSION-ENABLING TECHNOLOGY CANDIDATE
- MISSION-ENHANCING TECHNOLOGY CANDIDATE
- FUNDED TECHNOLOGY PROGRAM
- UNFUNDED TECHNOLOGY PROGRAM
- STATE-OF-THE-ART TECHNOLOGY
- HIGH, MEDIUM, LOW BENEFIT RATINGS

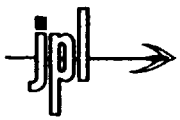
TECHNOLOGY READINESS STUDY
STUDY APPROACH



TECHNOLOGY READINESS STUDY

TECHNOLOGY ASSESSMENT - PRODUCTS

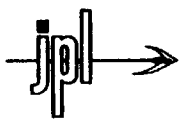
- RESULTS
  - IDENTIFICATION OF MISSION-ENABLING CANDIDATES
  - BENEFITS PROVIDED BY MISSION-ENHANCING CANDIDATES
  - STATE OF COMMITABILITY OF CANDIDATE TO PROJECT
- RECOMMENDATIONS
  - INCLUSION OR EXCLUSION OF CANDIDATES IN BASELINE DESIGN
  - TECHNOLOGY DEVELOPMENT PROGRAM RECOMMENDATIONS



TECHNOLOGY READINESS STUDY

TECHNOLOGY ASSESSMENT - PREPARATION

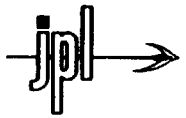
- MISSION IDENTIFICATION
  - MISSION OBJECTIVES
  - MISSION SCHEDULE
  - MISSION CONSTRAINTS
  - BASELINE IMPLEMENTATION SCHEME
- TECHNOLOGY CANDIDATE SOURCE IDENTIFICATION
  - LIMITATIONS OF TIME AND AVAILABILITY
  - COGNIZANCE OF BASIS FOR TECHNOLOGY ADVANCEMENT



TECHNOLOGY READINESS STUDY

TECHNOLOGY ASSESSMENT - APPROACH

- TECHNOLOGY BENEFITS ASSESSMENT
- TECHNOLOGY READINESS ASSESSMENT
- GENERATION OF DEVELOPMENT PROGRAM RECOMMENDATIONS



TECHNOLOGY READINESS STUDY

TECHNOLOGY BENEFITS ASSESSMENT

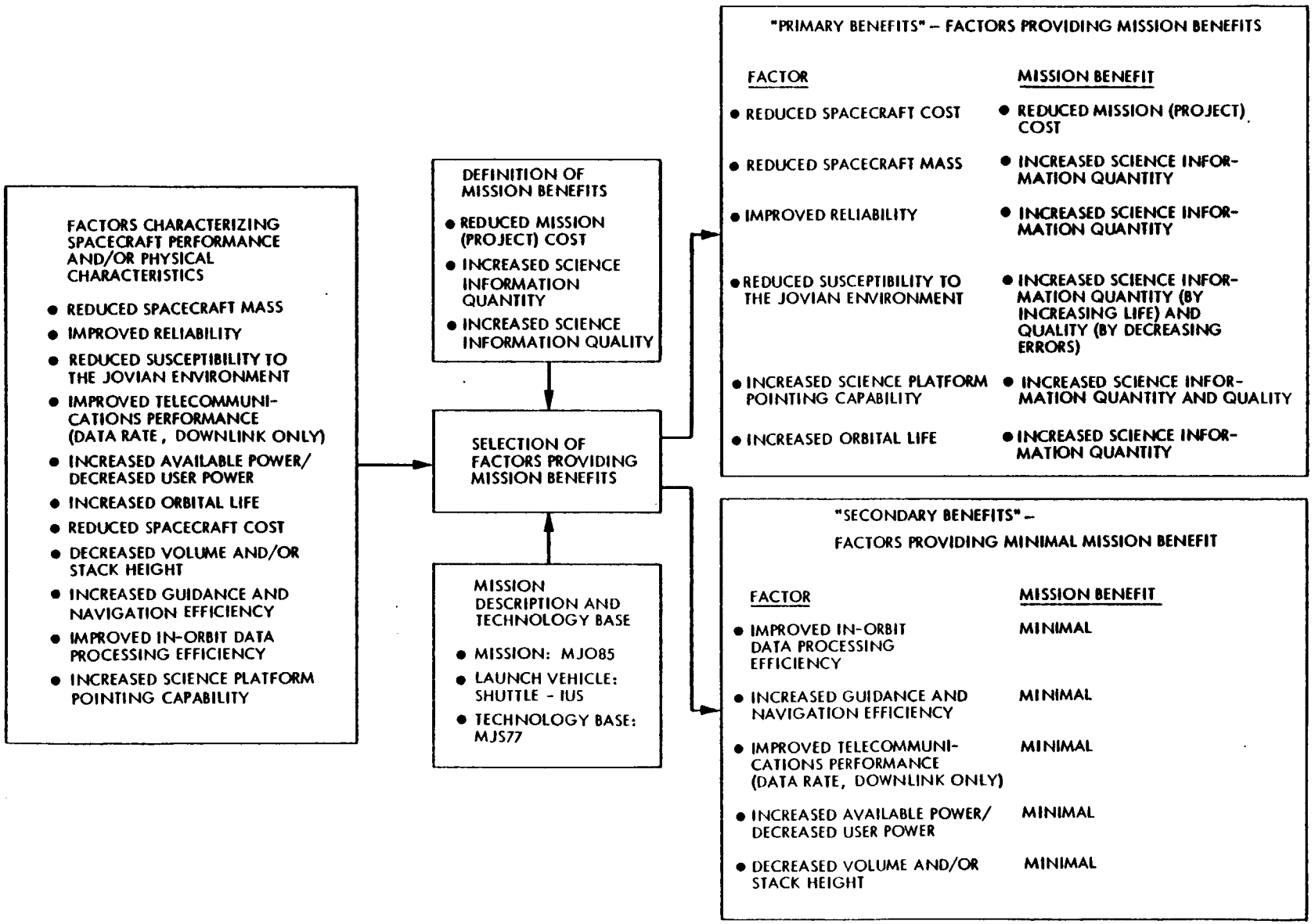
MISSION-ENABLING TECHNOLOGY CANDIDATE IDENTIFICATION

- REMEDIES DEFICIENCY IN BASELINE IMPLEMENTATION SYSTEM
- NO FURTHER BENEFITS ASSESSMENT PERFORMED

MISSION-ENHANCING TECHNOLOGY CANDIDATE ASSESSMENT

- BASELINE IMPLEMENTATION SYSTEM PERFORMANCE ATTRIBUTES
- EXAMINATION OF THESE FACTORS FOR ADEQUATE PERFORMANCE
- IDENTIFICATION OF PRIMARY AND SECONDARY MISSION BENEFITS
- ENUMERATION OF BENEFITS PROVIDED BY TECHNOLOGY CANDIDATE
- CLASSIFICATION OF CANDIDATE

TECHNOLOGY READINESS STUDY
IDENTIFICATION OF MISSION BENEFITS



TECHNOLOGY READINESS STUDY

CANDIDATE BENEFIT RATINGS

RATING	QUALITATIVE RATING SCHEME	QUANTITATIVE RATING SCHEME*	SELECTION STATUS FOR NEXT-GENERATION MARINER
HIGH	PROVIDES THREE OR MORE PRIMARY BENEFITS	NUMERICAL RATING ≥ 12	INCLUDED
MEDIUM (THRESHOLD)	PROVIDES TWO PRIMARY BENEFITS	NUMERICAL RATING < 12, ≥ 1	SELECTION DEPENDENT ON ENGINEERING JUDGMENT
LOW	PROVIDES ONE PRIMARY BENEFIT	NUMERICAL RATING < 1	EXCLUDED

* SEE PP53-55 AND TABILE XIV OF REPORT

TECHNOLOGY READINESS STUDY

TECHNOLOGY READINESS ASSESSMENT

- MISSION-ENABLING CANDIDATES
  - STATE-OF-DEVELOPMENT ASSESSMENT
  - DEVELOPMENT RISK ASSESSMENT
- MISSION-ENHANCING CANDIDATES
  - STATE-OF-DEVELOPMENT ASSESSMENT
  - COMMITABILITY TO PROJECT ASSESSMENT

TECHNOLOGY READINESS STUDY
STATE-OF-DEVELOPMENT SCALE

Level	State of Development	
	Hardware*	Software
1	Basic principles observed and reported	Basic theory developed and published
2	Conceptual design formulated	Applicability to specific problems proposed
3	Conceptual design tested analytically or experimentally	Used to identify parts of existing mission design
4	Critical function or characteristic demonstrated	Favorable comparison with available mission results attained
5	Component or breadboard tested in relevant environment	Analyses required for reference future mission performed
6	Prototype or engineering model tested in relevant environment	Demonstration that all functions required for reference future mission can be performed to the required accuracy
7	Engineering model flight tested in the space environment	Software used in support of at least one previous mission

*Abstracted from GD Convair Rpt. No. CASD-NA5-75-016, "Future Payload Technology Requirements Study," June 1975.

TECHNOLOGY READINESS STUDY
CANDIDATE RISK ASSESSMENT SCALE

Area	Levels of Risk		
	Low	Medium	High
Technology	Technology exists and has been demonstrated in other equipment, corresponding to a state-of-development level of 5 or higher.	Technology exists but has never been demonstrated, corresponding to Level 3.	Technology does not exist and must be developed, corresponding to Level 1.
	Alternatives are being developed, although they are not yet proven.	Alternatives are possible but are costly in terms of physical parameters or $.	Alternatives do not exist.
	Parallel developments are possible.	Resources and schedule are marginal for parallel developments, but parallel developments are still possible.	Parallel developments are not possible.
Personnel	Implementing personnel are available who have successfully supported other projects and who are considered experts in their fields.	High quality personnel, but with limited project experience, are available.	Personnel of unknown capabilities are available.
	Assignment and commitment of above personnel to project for its duration would be firm.	Personnel commitment to project is conditional.	Personnel commitment to project is undetermined.
Foreseeable Problems	Enough is known to foresee most major problems.	Enough is known to foresee some major problems.	Not enough is known to foresee major problems.
	Enough is known to foresee many minor problems.	Enough is known to foresee some minor problems.	Not enough is known to foresee minor problems.

TECHNOLOGY READINESS STUDY
CRITERIA FOR COMMITMENT TO PROJECT

1. The candidate state of development must correspond to a level of 5-6 on the appropriate hardware or software State-of-Development Scale.

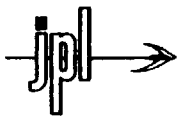
2. Requirements should not be placed on other subsystems which require their advancement beyond the state-of-the-art.

3. Components or piece parts (or their equivalents) must be available (and remain so) and must meet project quality requirements.

4. There must be no foreseeable problems to the technology candidate surviving and functioning in the expected environments.

5. Estimates of candidate mass, power, and volume must be within system capabilities.

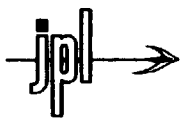
6. Cost, manpower, and schedule must be consistent with the project plan and resources.



TECHNOLOGY READINESS STUDY

DEVELOPMENT PROGRAM RECOMMENDATIONS

- NEEDS
  - TECHNOLOGY CANDIDATES SELECTED FOR INCLUSION
- STATUS
  - STATE-OF-DEVELOPMENT ASSESSMENT BASED ON CURRENT DEVELOPMENT PROGRAM
- CHANGE TO CURRENT DEVELOPMENT PROGRAM IDENTIFIED BY COMPARING STATUS TO NEEDS

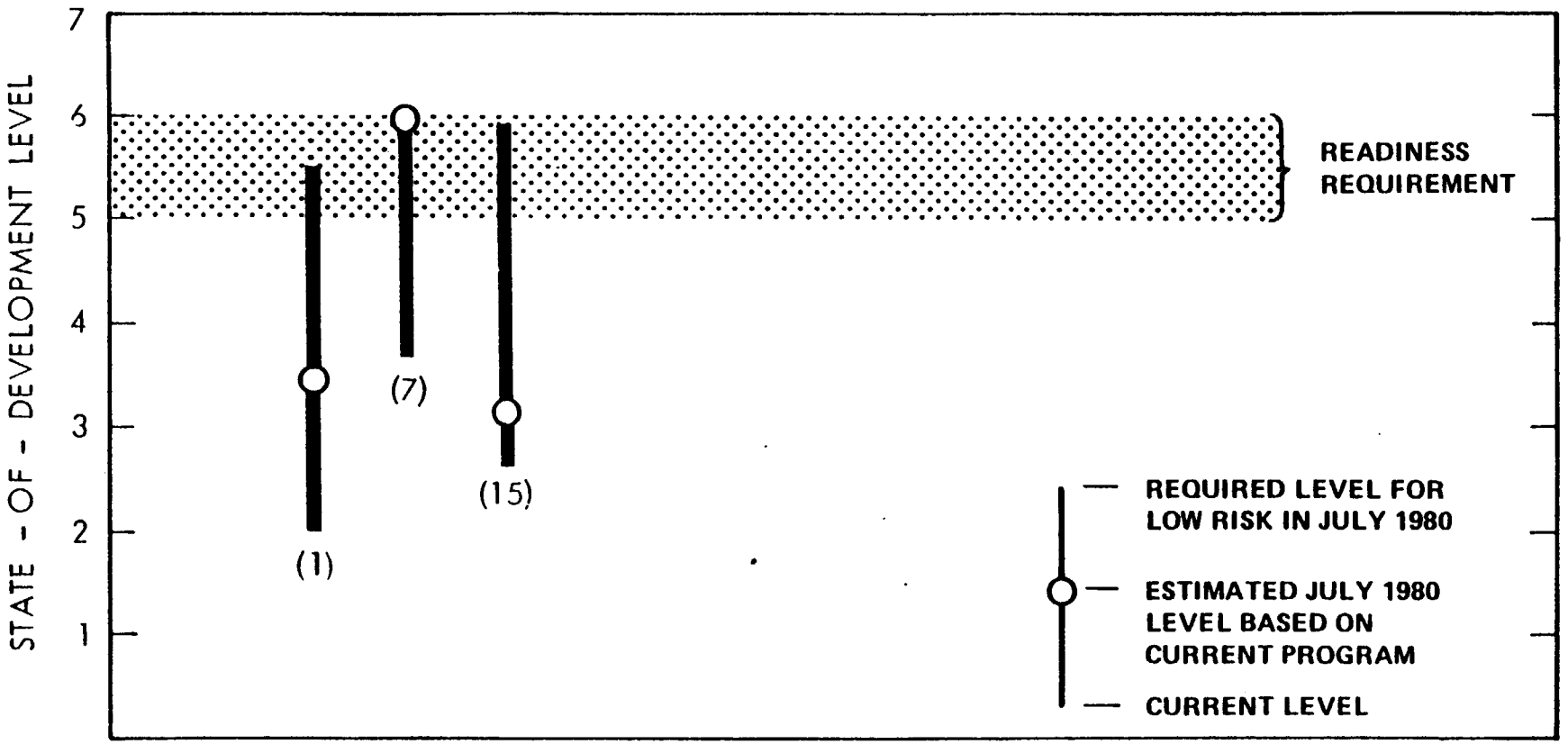


TECHNOLOGY READINESS STUDY
STUDY RESULTS

- TECHNOLOGY READINESS ASSESSMENT
  - FUNDED CANDIDATES NOT READY FOR PROJECT COMMITMENT
    - MISSION/NAVIGATION DESIGN AND ANALYSIS SOFTWARE
    - CCD OPTICAL GUIDANCE SENSOR
    - SOLAR ELECTRIC PROPULSION (LOW THRUST NAVIGATION SOFTWARE)
  - NO UNFUNDED CANDIDATES READY FOR PROJECT COMMITMENT
  - ALL STATE-OF-THE-ART CANDIDATES READY FOR PROJECT COMMITMENT

TECHNOLOGY READINESS STUDY

MISSION ENABLING CANDIDATES STATE-OF-DEVELOPMENT



(1) MISSION/NAVIGATION DESIGN AND ANALYSIS SOFTWARE

(7) BIPROPELLANT SPACE STORABLE PROPULSION SUBSYSTEM

(15) SOLAR ELECTRIC PROPULSION

TECHNOLOGY READINESS STUDY
STUDY RESULTS
(Contd)

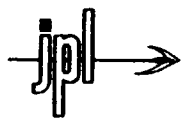
- TECHNOLOGY BENEFITS ASSESSMENT (NEEDS)
  - MISSION-ENABLING CANDIDATES
    - MISSION/NAVIGATION DESIGN AND ANALYSIS SOFTWARE
    - BIPROPELLANT SPACE STORABLE PROPULSION SUBSYSTEM

      OR

    - SOLAR ELECTRIC PROPULSION
  - MISSION-ENHANCING CANDIDATES
    - EIGHT RATED HIGH MISSION BENEFIT
    - FOURTEEN RATED MEDIUM MISSION BENEFIT
    - SIX RATED LOW
  - FOUR NEXT-GENERATION MARINER SPACECRAFT DESIGNS SYNTHESIZED
  - FIVE VIABLE SPACECRAFT DESIGNS IDENTIFIED

TECHNOLOGY READINESS STUDY
SPACECRAFT DESIGN CANDIDATES

Spacecraft Candidate	Description of Candidate	Performance Feasibility for Reference Mission
Reference	Conventional Mariner mission module (MM); Viking 75 (VO75) bipropellant earth storable propulsion module (PM).	Infeasible, margin of -289.0 kg
Reference with Solar Electric Propulsion (SEP)	(same as above plus SEP)	Feasible, margin of +3.0 kg
Next-Generation Mariner Option A	Modified conventional Mariner MM: bipropellant space storable PM.	Feasible, margin of 71.2 kg
Next-Generation Mariner Option B	Unified Data Subsystem (UDS)-based MM; bipropellant space storage PM.	Feasible, margin of 130.8 kg
Next-Generation Mariner Option C	Modified conventional Mariner MM; monopropellant earth storable/solar electric PM.	Feasible, margin of 12.2 kg
Next-Generation Mariner Option D	UDS-based MM; monopropellant earth storable/solar electric PM.	Feasible, margin of 99.8 kg



TECHNOLOGY READINESS STUDY
STUDY RECOMMENDATIONS

MISSION-ENABLING CANDIDATES

PROGRAM AUGMENTATION ESSENTIAL FOR MISSION/NAVIGATION DESIGN AND ANALYSIS SOFTWARE TECHNOLOGY CANDIDATE

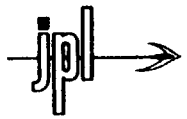
AUGMENTATION OF SOLAR ELECTRIC PROPULSION PROGRAM WOULD PROVIDE ALTERNATE TO SPACE STORABLE PROPULSION

MISSION-ENHANCING CANDIDATES

FUNDING OF PROGRAMS DESIRABLE FOR ADVANCED IMAGING COMMUNICATION SUBSYSTEM AND PRECISION LONG-RANGE SUN SENSOR CANDIDATES

ADDITIONAL SUPPORT FOR GRADUAL IMPROVEMENT IN TECHNOLOGY DESIRABLE FOR HYBRID PACKAGING AND PIECE PART RADIATION SHIELDING

OTHER CANDIDATES SELECTED FOR INCLUSION IN NEXT-GENERATION MARINER SPACECRAFT DESIGN DO NOT REQUIRE PROGRAM AUGMENTATION OR INITIATION



TECHNOLOGY READINESS STUDY

STUDY CONCLUSIONS

METHODOLOGY IS A VIABLE TOOL FOR IDENTIFYING TECHNOLOGY PROGRAM NEEDS AND PRIORITIES REFERENCED TO SPECIFIC MISSIONS

REFINEMENT IN METHODOLOGY WOULD PROVIDE EXPLICIT STATEMENT OF MISSION-ENHANCING CANDIDATE RISK LEVELS

BROADER EXAMINATION OF THE IMPACT ON THE PROJECT SYSTEMS OF ADOPTION OF TECHNOLOGY CANDIDATES IS WARRANTED

QUANTIFICATION OF CRITERIA FOR ASSIGNMENT OF CANDIDATE NUMERICAL VALUES WOULD BE BENEFICIAL